Journal of Forensic and Legal Medicine 16 (2009) 67–69

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/jflm

Original Communication

Limitations of the mandibular canine index in sex assessment

Ashith B. Acharya BDS GDFO [a,1,*], Sneedha Mainali BDS [b,2]

[a] Department of Forensic Odontology, S.D.M. College of Dental Sciences and Hospital, Sattur, Dharwad, Karnataka State 580 009, India
[b] College of Dental Surgery, B.P. Koirala Institute of Health Sciences, Dharan, Nepal

ARTICLE INFO

Article history:
Received 9 April 2008
Accepted 16 August 2008
Available online 1 October 2008

Keywords:
Forensic odontology
Dental anthropology
Sex determination
Standard MCI
Discriminant analysis

ABSTRACT

Measuring teeth is a useful adjunct in sex assessment. Canines, in particular, have the greatest degree of sexual dimorphism, resist disease and survive postmortem trauma, rendering them highly valuable in identification. Hence, their exclusive use in odontometric sex assessment using the Mandibular Canine Index (MCI) has been advocated before. The MCI is derived as the ratio of the mesiodistal (MD) dimension of canines and the inter-canine arch width. This study has tested the use of the MCI in assessing sex on a sample from Nepal and compared its accuracy to that of absolute canine measurements. Measurements were obtained from one hundred-and-seventeen dental stone casts that belonged to 63 males and 54 females, all young adults in the age-group 19–28 years. Independent samples *t*-test revealed no significant sexual dimorphism in the MCI. In addition, discriminant analysis of the MCI also had poor ability to differentiate the sexes. In contrast, the absolute canine measurements revealed statistically significant male–female difference and superior ability to differentiate sex using discriminant analysis. The poor ability of the MCI in sex assessment is attributed to it being a relative value–it is obtained as the ratio of two absolute measurements (MD dimension of canines and inter-canine arch width) and does not reflect sex differences that exist in the absolute measurements per se.

1. Introduction

Sex assessment constitutes an important step in constructing a postmortem profile and is useful in identifying skeletal remains. The accuracy of sexing using diverse parameters of the body such as craniofacial morphology and measurements on the pubis ranges from 96% to 100%.[1,2] Correct sex identification limits the pool of missing persons to just one half of the population. In forensic contexts, however, it is not uncommon to recover partial remains, with fragmentary skull and pelvic bones. The teeth are one of the strongest human tissues and are known to resist a variety of peri- and postmortem insults. Also, since the human dentition has a complement of 32 teeth, at least a few teeth are usually recovered. Hence, they are routinely used in comparative identification of human remains. The dentition is also considered a useful adjunct in sex determination. The fact that most teeth complete development before skeletal maturation makes the dentition a valuable sex indicator, particularly in young individuals.[3]

Among the teeth, canines have consistently shown the greatest sexual dimorphism.[3–8] In addition, canines are among the toughest teeth and less susceptible to disease. It was for these reasons that Rao et al. [9] proposed the exclusive use of mandibular canines in sex identification. The authors developed an index, which they named Mandibular Canine Index (MCI), and was derived as follows:

$$\mathrm{MCI} = \frac{\text{Mesiodistal crown width of mandibular canine}}{\text{Mandibular inter-canine arch width}}.$$

The mean and standard deviation (S.D.) of the MCI was derived separately for males and females and a cut-off point–termed the 'Standard MCI'–to distinguish the sexes calculated as follows:

$$\text{Standard MCI} = \frac{(\text{Mean male MCI} - \text{S.D.}) + (\text{mean female MCI} + \text{S.D.})}{2}$$

If the MCI value is less than or equal to the Standard MCI, the individual is categorised as female; a value more than the Standard MCI would group the person as male. The approach is considered to be a simple and rapid means of sex assessment.[10] Therefore, we have ventured to test its effectiveness in sexing a sample from Nepal. Rao et al.'s use of a cut-off point for sex assessment (the Standard MCI)[9] has similarities to multivariate discriminant analysis, which is based on the generalised squared distance classification technique. A comparison of the two methods found that discriminant analysis gave better results in sex assessment.[11] Hence, we have also endeavoured to compare the success of the two statistical approaches.

* Corresponding author. Tel.: +91 836 2468142x503; fax: +91 836 2467612.
E-mail address: ashithacharya@hotmail.com (A.B. Acharya).

[1] This author conceived and planned the study as well as scrutinised the data and results to draw inferences.
[2] This author obtained the data and planned part of the methodology.

1752-928X/$ - see front matter © 2008 Elsevier Ltd and Faculty of Forensic and Legal Medicine. All rights reserved.
doi:10.1016/j.jflm.2008.08.005

2. Materials and methods

2.1. Sample

The base sample comprised of 123 adults of Nepalese extract (65 males and 58 females). All subjects were undergraduate students of dentistry enrolled in B. P. Koirala Institute of Health Sciences, Dharan, Nepal, whose ages ranged from 19 to 28 years. Following informed verbal consent, impressions of the dentitions were made with irreversible hydrocolloid (alginate) material and casts poured in dental stone.

2.2. Measurements

Mesiodistal (MD) dimension of the mandibular canines and the mandibular inter-canine arch width were measured on the casts using a digital calliper with calibration 0.01 mm (Mitutoyo, Japan). The MD dimension was defined as the greatest distance between contact points on the approximate surfaces of the tooth crown.[12] In case of tooth rotation or malposition, the measurements were obtained between points where it was considered that contact with adjacent teeth should have normally occurred. The measurements were taken with the calliper beaks placed occlusally along the long-axis of the tooth. The inter-canine arch width was measured between the tips of both mandibular canines.[9] These measurements were also taken with the calliper beaks placed along the long-axes of the teeth. In case of attrition, where canine tips were worn out, the labial ridge was taken as an indicator of the anatomical tip since, incisally, it corresponds to the canine tip. Due to missing incisors in a few of the 123 dental casts, the inter-canine arch width (and, consequently, the MCI) was obtained for 54 females and 63 males, totalling 117 dentitions. Measurements were repeated on 18 randomly selected dental casts to evaluate intra- and inter-observer variation.

2.3. Statistical analyses

The repeat readings were compared to the base measurements using the paired samples *t*-test. Potential sex differences in the MD dimension of right and left canines as well as inter-canine arch width were tested using the independent samples *t*-test. The MCI was calculated for each dental cast as the ratio of the maximum MD canine dimension (the right or left canine, whichever was greater) and the inter-canine arch width. Descriptive statistics for the MCI were obtained and possible sex differences in it also examined using the independent samples *t*-test. The Standard MCI was then derived and used as a cut-off point to identify the sexes. Standard MCIs reported previously[9,10] were also used as cut-off points to test the effectiveness of Standard MCIs derived from other populations on the Nepalese. In addition, the MCI derived in the present population was subjected to discriminant analysis and the sex classification accuracy compared to that of Standard MCIs. Furthermore, with a view to compare the accuracy of sex determination of MCI and absolute measurements, discriminant analysis was also undertaken for the latter, particularly MD dimension of canines. All statistical analyses were performed on an MS Office 2007 Excel spreadsheet (Microsoft Corp., Redmond, Washington, USA) and SPSS 10.0 statistical software programme (SPSS Inc., Chicago, Illinois, USA).

3. Results

No significant intra- and inter-observer differences existed in the 18 repeat measurements ($p > 0.05$). Table 1 depicts the descriptive statistics and the degree of sexual dimorphism for MD measurement of canines, the inter-canine arch width and the MCI. The MD canine dimensions as well as the inter-canine arch width were statistically larger in males ($p < 0.01$) whereas the MCI revealed no significant sex differences ($p = 0.37$). Table 2 shows the sex differentiation accuracy of Standard MCIs derived in the present and two previous studies. Overall, all Standard MCIs show low accuracy in sexing the Nepalese, with the Standard MCI derived on the present population performing the worst. Table 3 shows the sex classification accuracy of discriminant analysis performed for the MCI and MD dimension of canines. The sex identification accuracy of the MCI using discriminant analysis is marginally higher to that of the Standard MCIs in Table 2. However, the accuracy is lower to that of discriminant analysis undertaken for MD dimension of canines.

Table 1
Descriptive statistics and *t*-values for MD dimension of mandibular canines (in mm), inter-canine arch width (in mm) and the MCI

Variable	Sex	N	Mean	S. D.	*t*-Value
MD of right canine	Female	58	6.58	0.35	−5.60[a]
	Male	65	6.96	0.39	
MD of left canine	Female	58	6.62	0.35	−5.54[a]
	Male	65	7.00	0.40	
Inter-canine Width	Female	54	25.56	1.87	−3.00[a]
	Male	63	26.74	2.29	
Mandibular canine index (MCI)	Female	54	0.261	0.0177	−0.87[b]
	Male	63	0.265	0.0247	

[a] Significantly larger in males at $p \leqslant 0.01$ level.
[b] No significant sex difference at $p \leqslant 0.05$ level.

Table 2
Comparison of the accuracy of sexing the Nepalese using Standard MCIs derived from different populations

Standard MCI	Males		Females		Total	
	Number	%	Number	%	Number	%
0.274[9]	21/63	33.33	43/54	79.63	64/117	54.70
0.269[10]	24/63	38.10	41/54	75.93	65/117	55.56
0.260[a]	36/63	57.14	24/54	44.44	60/117	51.28

[a] Derived on the present population.

Table 3
Sex classification accuracy of the cross-validated[a] samples by discriminant analysis

Discriminant analysis	Male		Female		Total average (%)
	N	%	*N*	%	
MCI	32/63	50.8	34/54	63.0	56.4
MD of Canines	44/65	67.7	41/58	70.7	69.1

[a] In cross-validation (or jackknifing), each case is classified by the functions derived from all cases other than that case.

4. Discussion

Rao and associates suggested that the canines be considered as a "key tooth" for sex assessment since they are consistently larger in males, less prone to dental disease and more likely to survive postmortem insults.[9] They calculated the MCI on a sample of 766 juveniles and young adults and found significant sexual dimorphism ($p = 0.001$). On the other hand, we found no statistically significant male–female differences (Table 1). However, the absolute measurements used to derive the MCI, viz. MD dimension of canines and inter-canine arch width were both significantly larger in males ($p < 0.01$).

Deriving the Standard MCI as a cut-off point to differentiate the sexes, Rao et al.[9] obtained a healthy 85.9% accuracy in sex identification. Later, Muller et al.[10] tested Rao et al.'s Standard MCI[9] on a French sample and could correctly identify sex in just 59.4% of cases. In an attempt to improve the accuracy they derived a separate Standard MCI on their sample, which marginally improved sex classification to ~63%. Considering this improvement, we ventured to develop a Standard MCI on our sample. We compared the effectiveness of this Standard MCI, as well as those derived earlier,[9,10] in sexing our sample. Surprisingly, the Standard MCI developed on our population proved less effective (Table 2)–the two earlier Standard MCIs[9,10] gave slightly higher sex identification rates, particularly since their ability to identify females was relatively high (Table 2). It is probable that minimal male–female differences in the mean MCI and large S.D. for males in the present population (Table 1) has resulted in a Standard MCI (0.260) which is actually less than both the male and female mean MCI–a contrast to earlier studies where, Standard MCIs were approximately midway between male and female mean MCI.[9,10] This has resulted in gross misidentification of females relative to the earlier two Standard MCIs, reducing the overall sex identification accuracy. The variable patterns of accuracy may be attributed to our Standard MCI being derived on just 117 subjects as compared to much larger samples used previously.[9,10]

Correct sex classification from discriminant analysis of MCI was marginally higher at 56.4% (Table 3). This is consistent with Sherfudhin and colleagues' implicit observation that statistical treatment of canine measurements affects sex identification outcome.[11] These authors attribute the difference to the statistical basis of Rao et al.'s MCI[9] and multivariate discriminant analysis. According to them, the former method employs two parameters (MD dimension of canine and inter-canine arch width) to develop a quotient, using which sex is identified. On the other hand, discriminant analysis uses a vector of more than two parameters. Furthermore, the method of Rao et al.[9] uses S.D. of males and females. Discriminant analysis utilises co-variance in addition to S.D., allowing more critical investigation of the data.[11]

Interestingly, discriminant analysis of MD measurement of canines gave recognisably greater sex classification accuracy (69.1%) than discriminant analysis of the MCI (Table 3). The figure is comparable to the 74.3% accuracy obtained by Anderson and Thompson,[13] who also supported the use of MD dimension of canines in sex determination. This raises the question as to why MCI shows negligible sex difference in the present study (Table 1) and has had such poor success in identifying sex (Tables 2 and 3)–a contrast to MD dimension of canines. A probable explanation is that the MCI is a relative value, obtained as the ratio of two absolute measurements (MD dimension of canines and inter-canine arch width), and does not reflect sex differences that exist in absolute measurements per se. This can best be illustrated by a hypothetical case:

Let us consider a male canine dimension of 8 mm and inter-canine arch width of 32 mm. Let us also consider a female canine dimension of 6 mm and inter-canine width of 24 mm. Although the male dimensions are 33.33% larger than that of the female, the MCI for both would remain the same ($8/32 = 6/24 = 0.25$).

It is, therefore, unsurprising that the MCI fails to show significant univariate sex differences (Table 1). This inability of the MCI to reflect sex dimorphism that exists in absolute measurements could also be responsible for poor sex classification using discriminant analysis (Table 3). In addition, the inter-canine arch width requires that all canines and incisors be present in the mandible. In the event one of these teeth is congenitally missing, fail to erupt or has been extracted early in life, the inter-canine arch width and, consequently, the MCI can not be derived. Also, in skeletal specimens, canines may be mobile due to compromised periodontal support. In such instances the inter-canine arch width and the resulting MCI may be erroneous. Furthermore, the method is primarily dependent on one type of tooth namely, the canine. While this makes the method simple and convenient, the end result, i.e. sex assessment, may be sub-optimal. Indeed, a recent study on our sample has shown high sex identification accuracy (92.5%) from discriminant analysis of all teeth.[8] We recognise that canines reveal the greatest and most consistent sex dimorphism in the dentition, but believe sex assessment is best accomplished using measurements of as many teeth as are available, rather than indices or individual teeth.

Acknowledgments

The authors wish to thank students of the College of Dental Surgery, B.P. Koirala Institute of Health Sciences, Dharan, Nepal, who contributed their dental casts for the study. The first author is grateful to Prof. C. Bhasker Rao, Principal of S.D.M. College of Dental Sciences and Hospital, Dharwad, for his continued support to research in the subject.

References

1. Williams BA, Rogers TL. Evaluating the accuracy and precision of cranial morphological traits for sex determination. *J Forensic Sci* 2006;**51**(4):729–35.
2. Luo Y-C. Sex determination from the pubis by discriminant function analysis. *Forensic Sci Int* 1995;**74**:89–98.
3. Lund H, Mörnstad H. Gender determination by odontometrics in a Swedish population. *J Forensic Odontotomatol* 1999;**17**:30–4.
4. Garn SM, Lewis AB, Swindler DR, Kerewsky RS. Genetic control of sexual dimorphism in tooth size. *J Dent Res* 1967;**46**(Suppl. 5):963–72.
5. Townsend GC, Brown T. Tooth size characteristics of Australian aborigines. *Occas Pap Hum Biol* 1979;**1**:17–38.
6. Ghose LJ, Baghdady VS. Analysis of the Iraqi dentition: mesiodistal crown diameters of permanent teeth. *J Dent Res* 1979;**58**:1047–54.
7. İşcan MY, Kedici SP. Sexual variation in buccolingual dimensions in Turkish dentition. *Forensic Sci Int* 2003;**137**:160–4.
8. Acharya AB, Mainali S. Univariate sex dimorphism in the Nepalese dentition and the use of discriminant functions in gender assessment. *Forensic Sci Int* 2007;**173**(1):47–56.
9. Rao NG, Rao NN, Pai ML, Kotian MS. Mandibular canine index: a clue for establishing sex identity. *Forensic Sci Int* 1989;**42**:249–54.
10. Muller M, Lupi-Pegurier L, Quatrehomme G, Bolla M. Odontometrical method useful in determining gender and dental alignment. *Forensic Sci Int* 2001;**121**:194–7.
11. Sherfudhin H, Abdullah MA, Khan N. A cross-sectional study of canine dimorphism in establishing sex identity: comparison of two statistical methods. *J Oral Rehab* 1996;**23**:627–31.
12. Moorrees CFA, Thomsen SØ, Jensen E, Yen PK-J. Mesiodistal crown diameters of the deciduous and permanent teeth in individuals. *J Dent Res* 1957;**36**(1):39–47.
13. Anderson DL, Thompson GW. Interrelationships and sex differences of dental and skeletal measurements. *J Dent Res* 1973;**52**(3):431–8.